Elevated Skid Design for an Unmanned Disaster Relief Helicopter

Umair Iqbal[1]*, Muhammad Salman Sadiq[2], Aiman Rashid[2] and Syed Irtiza Ali Shah[1]

[1]Department of Robotics and Artificial Intelligence (R&AI), National University of Sciences and Technology (NUST), Sector H-12, Islamabad, Pakistan
[2]Department of Design and Manufacturing Engineering (DME), National University of Sciences and Technology (NUST), Sector H-12, Islamabad, Pakistan
*e-mail: umair.choudhry@smme.edu.pk, irtiza@smme.nust.edu.pk
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Abstract

Development of unmanned disaster relief helicopters is need of developing countries like Pakistan to save the lives of disaster victims. As a part of research on the development of unmanned disaster relief helicopter at National University of Sciences and Technology (NUST), this paper aims to address the problems of installing disaster relief equipment on a Radio Controlled (RC) model helicopter. Skid elevation is essential in order to facilitate the installation of disaster surveying equipment like video and data telemetry system. This paper proposes an elevated skid design as a potential solution to the problem. The Structure of elevated skid has been simulated for the static structural analysis to check its safety and reliability. Simulation results and overall design of proposed elevated skid has been compared with the existing skids. Virtual Computer Aided Design (CAD) PRO-E has been used for the modeling of elevated skid and ANSYS has been used for the simulations of proposed design. Proposed elevated skid has been specifically designed for the 90 size model helicopters and can be utilized to attach the additional imagery and data telemetry equipment beneath the helicopter.

Keywords: Model Helicopters, CAD, Disaster Relief, Unmanned Surveying, Mechanical Structure and Static Structural Analysis.

Abbreviations

RC	Radio Controlled
UAV	Unmanned Aerial Vehicle
EDM	Electrical Discharge Machining
CAD	Computer Aided Design
CG	Centre of Gravity

Introduction

In most of the developed countries, unmanned aerial vehicles have become reliable and most often used platforms for disaster surveying and relief purposes. In literature, different researchers proposed the use of small and medium-size unmanned aerial vehicles (UAVs) for monitoring, surveying and remote sensing purposes [1-3]. UAVs are becoming popular for surveying and monitoring applications due to their advantages of cost efficiency, safety, reliability and quick response. Out of many available aerial platforms, multi-rotor copters have been considered as one of the best choices for the disaster surveying and relief operations because of their agile flight movements, hovering capabilities and low altitude flights [4-6].

In order to develop an unmanned disaster relief aerial vehicle, mostly the researchers use already available aerial platforms and modify them to achieve desired functionality. This approach on the one end saves a lot of time in the overall development process but on the other hand requires structural changes in the available platforms. For a disaster relief helicopter, the essential systems include the long range radio control system, high-quality imagery and data telemetry equipment, auto-pilot system and surveying sensors payload [7]. Usually, the radio control system and the autopilot system can be facilitated by the existing structure without any substantial changes but vision and sensory equipment mounting require more space which best can be provided underneath the vehicle. The default landing skid in RC helicopters is not elevated enough to accommodate the additional systems and hence an elevated skid design is required. In literature, few researchers worked on the designing and simulations of the helicopter landing skids [8-11], but skid elevation for RC helicopters still needed to be explored in detail.

The aerial Robotics lab, NUST is in the process of developing a fully equipped unmanned helicopter for disaster relief and surveying purposes. The problem of skid elevation was observed during the detailed study of the model helicopter for the mounting of long-range vision system [12] and airdrop mechanism [13]. It is a challenging task to modify the default skid structure because it might affect the overall Centre of Gravity (CG) of the helicopter and flight dynamics.

This paper proposes an elevated helicopter skid design as a solution to the problem of attaching vision and sensory equipment beneath the helicopter. The paper presents the details of the exciting skids, proposed skid modeling, static structural analysis of proposed design and comparison with the existing skids.

Existing Helicopter Skids and Design Requirements

Velocity 90 nitro model RC helicopter has been used as a base platform for the research. Default helicopter skid is not elevated enough to facilitate the installation of any additional systems as the helicopter is not meant to carry a payload. In this research, two exciting helicopter skids have been studied and based on the results of study new elevated skid design has been proposed. Existing helicopter skids are default skid by manufacturer and reference elevated skid initially fabricated as per load requirements of the helicopter.

Table 1: Detailed Specifications of Existing Helicopter Skids.

	Velocity 90 Default Skid	Reference Elevated skid
Dimensions (mm)	330*203*22	330*280*190
Material	Plastic + Steel	Copper
Mass (g)	125	450
Payload Capacity (kg)	4	15
Design	Default by Manufacturer	Fabricated as per Requirement

Reference elevated skid was initially designed for the mounting of video and data telemetry system. Materials used in the manufacturing of default skid and reference elevated skid are plastic and copper, respectively. Although the reference elevated skid facilitated the installation of the additional system, still it is important to mention that reference skid was fabricated without any prior modeling and testing hence not an optimised design for an aerodynamic structure. Detailed specifications of both the helicopter skids are given in Table 1. A helicopter without any additional system installed on it weighs 3.5kg and default helicopter skid has been designed for the mentioned gross weight of the helicopter. To transform the helicopter into disaster relief helicopter as mentioned earlier, additional systems needed to be installed. It has been estimated that additionally, at least 2kg of weight will increase after installing the additional systems. As a result, designed elevated skid must be capable of bearing at least 5kg of weight. Furthermore, the elevated skid should not interact with the structure of the helicopter and should provide enough space underneath to facilitate the vision system. Also, the skid elevation should not affect the overall CG of the helicopter. The overall weight of the proposed skid should not exceed the 300g.

Modeling and Simulations of Elevated Skid

This section presents the details about the modeling of elevated helicopter skid and its respective static structural analysis to check the validity of design. Considering the payload capacity of the helicopter after customising (app 5.5kg), the elevated skid design been modeled and simulated. Standard design and manufacturing methods [14, 15] and flow [16] was used for the designing of the skid. Flow diagram of the methodology used for the designing of the elevated skid has been presented in Figure 1. Basically, proposed elevated skid design is a replication of default skid but elevated from 22mm to 95mm for mounting the vision and sensory equipment underneath. Elevated skid model consists of three main components, landing rods, holding clips and stand. The model of elevated skid has been designed considering the load conditions and available manufacturing resources. A fairly simple design has been proposed which can be manufactured using the Electrical Discharge Machining (EDM). Figure 2 shows the CAD assembly for the proposed elevated skid design. The structure of the elevated skid has been simulated for two different materials combinations, material combination1 [1], and material combination2 [2]. Overall these material combinations use four materials, structural steel, aluminum alloy, polyethylene, and fiberglass. Detailed available specifications of materials have been presented in Table 2. Both the simulated materials are often used for aerodynamic structures, however, aluminum alloy structures are little heavier than fiberglass with almost the same strength but the manufacturing of fiberglass structures is complex and expensive than aluminum alloy. Overall of CG of the helicopter was elevated in the vertical direction and remained unchanged in other two directions. Vertical shift of CG will cause the slight un-stability while the helicopter is on the ground but during the flight, overall CG will be slightly lower than the earlier, which will improve the in-flight stability of the helicopter.

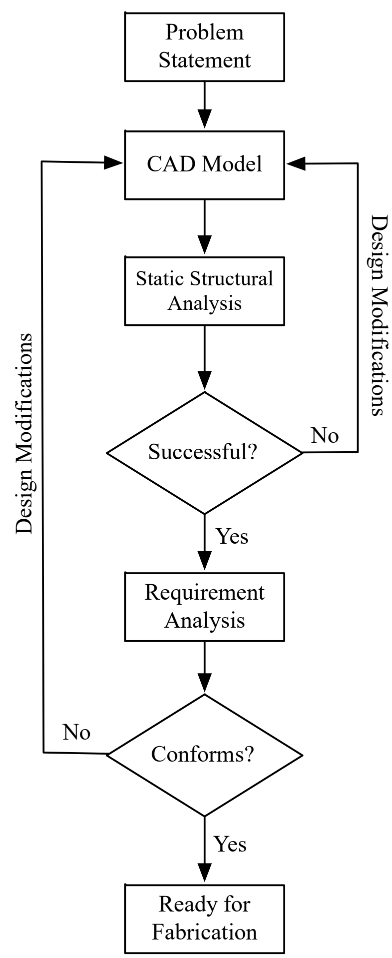


Fig. 1: Flow Diagram for the Implementation Proposed Elevated Skid.

[1] Material Combination1 = Structural steel landing rods + Polyethylene holding clips + Aluminum stand.
[2] Material Combintation2 = Structural steel landing rods + Polyethylene holding clips + Fiberglass stand.

Table 2: Detailed Specifications of Materials used in Elevated Helicopter Skid [17-18]

	Aluminum Alloy	Polyethylene	Structural Steel	Fiberglass
Young's Modulus (MPa)	71000	1100	2×10^5	68900
Tensile Ultimate Strength (MPa)	310	33	460	3310
Density (kgmm^{-3})	2.77×10^{-6}	9.5×10^{-7}	7.85×10^{-6}	2.44×10^{-6}
Bulk Modulus (MPa)	69608	2291	1.67×10^5	36225
Shear Modulus (MPa)	26692	387.3	76923	29121

Elevated skid structure has been simulated for reliability and integrity by performing the static structural analysis. Virtual simulation environment ANSYS Workbench has been used for the simulations of the elevated skid. ANSYS mechanical solver with direct settings has been used because the load was applied instantaneously. The static structural time solver was used since the applied load was static. Solver was configured with single step while a load of 70N was instantaneously applied from 0 to 1 second. Since the direct solver was used, single iteration was required for the solver model. Multiple iterations are used by the software in case if the convergence solver model is used. Convergence criteria for the model was dependent on the mesh size, which was varied from coarse to fine and mesh control was refined over a number of iterations to study the mesh independence. Results were converged when the displacement values variations were within 10^{-4} with respect to the mesh size. Overall, a single solution of solver model took around 3 hours of time and the mesh refinement resulted in little increase in time but was on average the same. The model has been configured as per load requirements in the ANSYS and simulated. For simulations, a load of 70N along Y-axis has been applied on both stands with both the landing rods attached to the fixed supports.

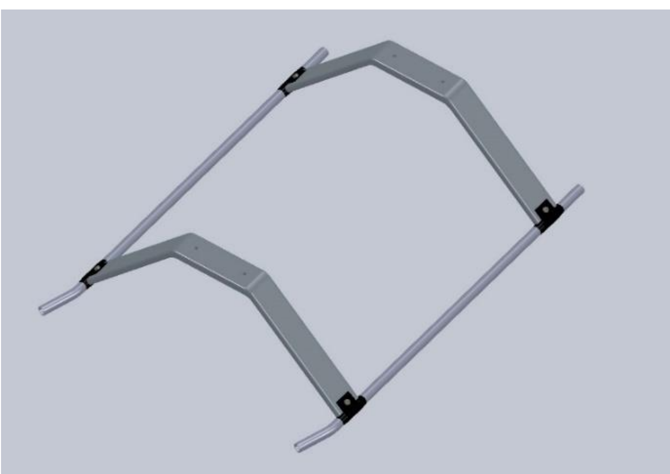


Fig. 2: CAD Model of 90mm Elevated Helicopter Skid

Results and Discussions

This section presents the results of the static structural analysis, comparison and analysis of the skids for their utilization in disaster survey and relief applications. The analysis results are presented in color countering to better explore the effect of loads and other constraints on the structure. In color contouring, the effect is distributed in between blue (the minimum) to the red (the maximum).

Results of the static structural analysis for the elevated skid for material combination1 and material combination2 are shown in Figure 3 and Figure 4, respectively. For aluminum material, total deformation and von-Misses results are shown in Figure 3(a) and Figure 3(b). Maximum deformation for aluminum under the specified load conditions has been recorded as 5.089×10^{-3} mm, which is within the safe limits of the material. Maximum equivalent stress has been recorded as 2.809 MPa, which shows that the structure is within the safe limits. Safety factor for the aluminum material is calculated and shown in Equation 1.

$$\text{Safety Factor} = \frac{\text{Yield Strength of Material}}{\text{Maximum Equivalent Stress}} = \frac{280}{2.80} = 100 \qquad (1)$$

For fiberglass material, total deformation and von-Misses results are shown in Figure 4(a) and Figure 4(b), respectively. Maximum deformation of fiberglass material has been recorded as 5.22×10^{-3} mm, which is within the safe limits. Maximum equivalent stress has been recorded as 2.732 MPa, which shows that the structure is way within the safe limits. Safety factor for the fiberglass is calculated and shown in Equation 2.

$$\text{Safety Factor} = \frac{\text{Yield Strength of Material}}{\text{Maximum Equivalent Stress}} = \frac{300}{2.73} = 110 \qquad (2)$$

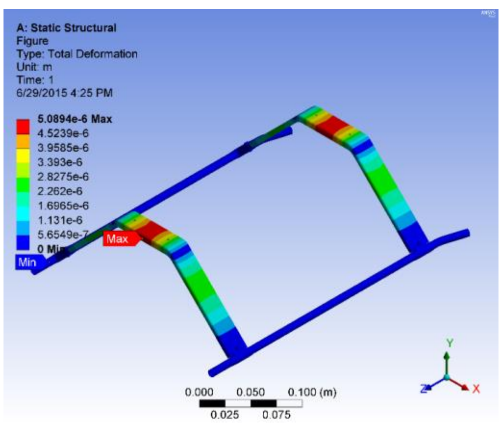
Table 3 presents the summary of the static structural analysis performed on the elevated skid for both aluminum and fiberglass materials. The table compares the results of both materials and concludes that for fiberglass and aluminum analysis yields 90 percent similarity in results but fiberglass is lighter than the aluminum, which optimizes the use of fiberglass for aerial applications. Table 4 compares the proposed elevated skid design with the existing skids in terms of features such as dimensions, mass, price, payload manufacturing, and reliability. In terms of mass, proposed design is heavier than the default skid but 200g lighter than the reference skid. The proposed design has an elevation of 90mm, which is lesser than reference skid but can easily accommodate the vision system. The proposed design is highly reliable as concluded from simulations and efficient because of standard design methodology. Payload capacity of designed skid is 7.5kg, lesser than the reference skid but still 2kg more than the required payload of the helicopter after modifications.

Table 3: Summary of the Static Structural Analysis for Elevated Helicopter Skid

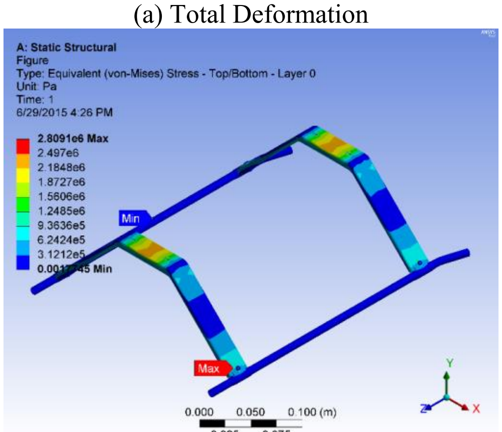
	Material Combination1	Material Combination2
Equivalent Stress (MPa)	2.809	2.732
Maximum Principle Strain	2.82×10^{-5}	2.931×10^{-5}
Maximum Equivalent Elastic Strain	3.315×10^{-5}	3.43×10^{-5}
Maximum Total Deformation (mm)	5.089×10^{-3}	5.22×10^{-3}
Maximum Deformation along Z (mm)	1.075×10^{-4}	5.93×10^{-5}
Maximum Deformation along Y (mm)	1.527×10^{-3}	1.566×10^{-3}
Maximum Deformation along X (mm)	2.07×10^{-3}	2.133×10^{-3}
Maximum Shear Strain	4.42×10^{-5}	4.07×10^{-5}
Maximum Shear Stress (MPa)	1.464	1.4257
Maximum Principle Stress (MPa)	2.023	2.0249

Table 4: Feature Based Comparison of Existing and Proposed Helicopter Skids.

	Default Skid	Reference Skid	Elevated Skid
Mass (g)	120	450	285
Dimensions (mm)	330×203×22	330×280×190	345×261×90
FPV Mount	No	Yes	Yes
Price	Low	Medium	Medium
Manufacturing	Default	Mold + Welding	EDM
Reliability	Low	High	High
Payload Capacity (kg)	4	10	7.5
Design Efficiency	High	Low	High

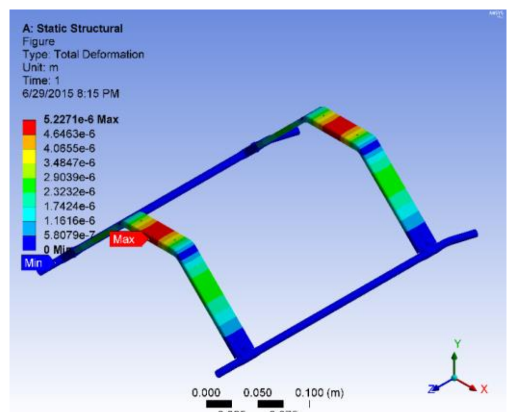


(a) Total Deformation

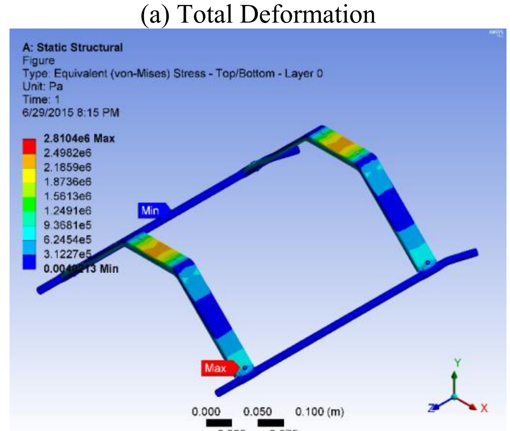


(b) Von-Misses Stress

Fig 3: Results of the Static Structural Analysis for Material Combination1



(a) Total Deformation



(b) Von-Misses Stress

Fig 4: Results of the Static Structural Analysis for Material Combination2

Conclusion

The research carried out in this article aimed to address the problem of skid elevation for mounting the additional systems and to propose potential solutions to the problem. Elevated helicopter skid has been proposed as a solution to the problem and successfully simulated for the required payload conditions. From the results of the static structural analysis presented in Figure 3, Figure 4 and Table 3, it has been concluded that proposed elevated skid lies within the safe limits for the specified load conditions. Furthermore, the skid was designed to avoid any possible interaction with the structure of the helicopter and provided enough space for the attachment of vision system. In addition, the overall CG of the helicopter was only altered in the vertical direction, while remained unaffected in other two directions. Skid elevation will improve the in-flight stability of the helicopter. Limitations of the proposed design include its inability to attach the airdrop mechanism and extra fuel tank along with the vision system. Proposed design can only accommodate the vision system, and more elevation in the design can cause the overweight issue. Furthermore, the design is not optimized for the weight as the safety factor values are very high, which indicates that the skid is overdesigned. Possible future dimensions of this research include the design simplifications, modifications in design to accommodate airdrop mechanism and extra fuel tank, explicit dynamic analysis of skid, and implementation of skid hardware to check its experimental validity.

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